Biomonitoring Results from Wilderness Streams in Idaho

G. Wayne Minshall, Christopher T. Robinson, and Todd V. Royer

Stream Ecology Center
Department of Biological Sciences
Idaho State University
Pocatello, Idaho 83209

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INTRODUCTION

The research goal for 1993 was to (1) continue monitoring study sites of the Big Creek catchment in the Frank Church River of No Return Wilderness; and (2) to sample additional sites in the Rapid River catchment of the Nez Perce National Forest. The Big Creek sites present an important wilderness monitoring opportunity because they represent a wide range of pristine stream types and are accessible (even during winter) from the University of Idaho's Taylor Ranch. Further, the Stream Ecology Center has been conducting research in this area since 1988. Four of the study streams were variously influenced by the Golden Fire in 1988 (Cliff, Cougar, Goat, and Dunce Creeks), and another, Cave Creek, acts as a south-facing reference site. In addition, two north-facing streams (Pioneer and Rush Creeks) provide an important contrast to the above south-facing sites, and were minimally affected by the Rush Point Fire of 1991. These streams, besides allowing examination of recovery from wildfire, contribute to determination of the natural variability found in relatively pristine stream ecosystems.

Four streams were sampled in the Rapid River catchment to assess the influence of wildfire on streams in a different geo-climatic area than that of the Big Creek catchment. Two streams were burned in the headwaters (Paradise and Copper), while two streams (Lake Fork and Granite Creeks) acted as the reference condition. We also have included data from 1992 for W.F. Rapid River and Castle Creek in this report to aid in interpretation of our findings from 1993. Logistic constraints precluded sample collections within the actual burn areas of Paradise and Copper Creeks. This, coupled with the relatively small size of the burned areas led us to expect to observe minimal impacts to the aquatic environs and associated biota.

METHODS

General field methods used for the various segments of this study are summarized in Table 1. The methods are consistent with methods used in our previous studies of wildfire and wilderness streams. These are relatively routine in stream ecology and are described in detail in standard reference sources (Weber 1973, Greeson et al. 1977, Lind 1979, Merritt and Cummins 1984, APHA 1989) or in more specific references listed in Table 1. The percent charcoal of BOM was determined by spreading the dried organic matter on a white piece of paper and visually estimating the %charcoal in quarterly increments (i.e.,0, 25, 50, 75, or 100%). Mean substratum size, water depths, and bottom velocities were determined at 100 random locations along a significant (ca. 200 meters) reach of stream. Habitat assessments for streams of the Big Creek watershed were completed following Robinson and Minshall (1994).

Methods for sampling macroinvertebrates are described in Platts et al. (1983). Procedures for sample analysis also are described in Table 1. Macroinvertebrates were examined in terms of density, biomass, species richness, Simpson's Index, and Shannon-Wiener diversity (H'). Diatom samples were collected in 1990 using methods found in Robinson and Rushforth (1987). Geographical locations of streams analyzed in the present report are summarized in Table 2. Streams were located on Big Creek in the Frank Church River of No Return Wilderness and on Rapid River in the Nez Perce National Forest. Streams sampled ranged in size from 2nd through 5th order.

RESULTS

Big Creek Catchment

Rush Creek displayed a reduction in discharge from 1.10

Table 1. Summary of variables, sampling methods, and analytical procedures used in the study.

Variable	Type*	Sampling Method	Analytical Method	Reference
A. Physical				
Temperature	P	Field measurement	Digital thermometer	
Substratum Size	R	Measure x-axis of 100 randomly selected substrata	Calculate mean substratum size	Leopold 1970
Substratum Embed-dedness	R	Visual estimation on 100 randomly selected substrata	Calculate mean substratum embededdness	Platts et al. 1983
Stream Width	T	Measure bank-full width using a nylon meter tape	Calculate mean stream width	Buchanan and Somers 1969
Stream Depth	R	Measure water depth at the 100 randomly choosen substrata	Calculate mean water depth	
Discharge	T	Velocity/depth profile Velocity measured with a small C-1 Ott meter	Q=WxDxV; where Q=discharge, W=width, D=depth, and V=vel	Bovee and Milhous 1978
B. Chemical				
Conductivity	P	Field measurement	Temperature comp-ensated meter (Orion model 126)	APHA 1989

* P=point measure; T=transect across stream; R=random throughout a defined reach.

Table 1 (cont.).

Variable	Type*	Sampling Method	Analytical Method	Reference
pH	P	Field measurement	Digital meter (Schott model CG837)	APHA 1989
Alkalinity	P	Single water sample	Methly-purple titration	APHA 1989
Hardness	P	Single water sample	EDTA titration	APHA 1989
C. Biological				
Invertebrates	R	Collect 5 samples using a Surber sampler	Remove invertebrates, identify, enumerate, and analyze community properties	Platts et al. 1983, Merritt and Cummins 1984
Periphyton	R	Collect samples from 5 individual substrata	Methanol extraction	Robinson and Minshall 1986
Benthic Organic Matter	R	Recovered from Surber samples	Determine AFDM	

* P=point measure; T=transect across stream; R=random throughout a defined reach.

Table 2. Location of study streams in the Big Creek and Rapid River catchments.

STREAM	Stream Order	Elevation (m)	Range	Township	Section No.	Coordinates
BIG CREEK CATCHMENT						
Rush Creek	5	1171	R13E	T20N	3	45 07'N, 114 51'W
Pioneer Creek	3	1165	R13E	T20N	3	45 06'N, 114 51'W
Cave Creek	3	1220	R12E	T21N	26	45 08'N, 114 57'W
Cliff Creek	2	1196	R13E	T20N	2	45 07'N, 114 51'W
Goat Creek	2	1125	R13E	T20N	1	45 07'N, 114 48'W
Cougar Creek	3	1095	R13E	T20N	1	45 07'N, 114 49'W
Dunce Creek	2	1159	R14E	T20N	5	45 07'N, 114 47'W
RAPID RIVER CATCHMENT						
Paradise Creek	3	1311	R1W	T22N	27	45 13'N, 116 27'W
Copper Creek	2	1098	R1W	T22N	15	45 15'N, 116 27'W
Lake Fork Creek	3	1739	R2W	T21N	1	45 11'N, 116 31'W
Granite Creek	3	1708	R2W	T21N	1	45 11'N, 116 31'W
W.F. Rapid River	4	1007	R1W	T23N	26	45 08'N, 116 25'W
Castle Creek	2	1129	R1W	T22N	11	45 15'N, 116 25'W

m^3/second in 1992 to 0.31 m^3/second in 1993 (Table 3). Discharge in Cliff Creek also declined from 1990/91 through 1992/93. Stream slope (gradient) has remained relatively constant in all study streams. Water chemistry parameters (alkalinity, hardness, specific conductance, and pH) also have remained stable over time, although these parameters (except pH) have varied by 40 units among years for any one site. Further, Goat and Dunce Creeks showed consistently greater values of specific conductance than did the other streams we examined suggesting differences in regional geology.

Maximum and minimum water temperatures for Pioneer and Rush Creeks from October 1991 through May 1993 are presented in Figure 1. Both streams displayed temperature maxima from approximately June through September 1992. The larger Rush Creek (5th order) was notably warmer than 3rd order Pioneer (maximum temperatures of 19 and 13°C, respectively). Minimum temperatures typically occurred in January and Feburary with readings below 0°C indicative of either super-cooling or anchor ice formation on the thermometer.

Habitat heterogeneity measures in the study streams have remained fairly similar over time (Table 4). The continuous decrease in substrate size within Dunce Creek is most likely an artifact of random sampling as reflected in the large standard deviations. This stream is extremely small having a bankfull width typically near 1 m. Measures of stream size and channel alteration (baseflow depth, bankfull width, and width:depth ratio) are nearly unchanged from previous years, suggesting stable channel conditions in all of the study streams. Near-bed stream velocities measured in 1993 showed values around 15 cm/s for all sites.

In addition to the above habitat measures, habitat assessments were generated for each the of the study streams (Table 5). In general, all sites showed total scores within 80%

Table 3. Physical and Chemical measures for study streams in the Big Creek catchment.

Stream	Year	Discharge (m3/s)	Slope (%)	Alkalinity (mg CaCO3/L)	Hardness (mg CaCO3/L)	Specific Conductance (umhos @ 20C)	pH
Rush	1988	1.61	1	36	30	110	7.8
	1991	NA	1	NA	NA	103	8.2
	1992	1.1	1	46	46	95	8.4
	1993	0.31	3	NA	NA	NA	7.9
Pioneer	1990	0.16	3	62	86	88	8.1
	1991	0.01	3	NA	NA	125	8
	1993	0.02	6	26	48	72	NA
Cave	1990	0.31	6	24	44	39	7.9
	1993	0.08	3	19	24	55	NA
Cliff	1990	0.32	10	35	66	61	8.2
	1991	0.18	11	77	71	73	8.2
	1992	0.08	9	48	49	99	8
	1993	0.09	6	26	44	77	7.7
Goat	1990	0.01	18	86	110	139	8.1
	1991	0.09	18	49	51	153	8.4
	1992	0.01	18	80	76	151	8.2
	1993	0.01	17	41	68	116	8.1
Cougar	1990	0.11	12	46	71	70	8.5
	1991	0.1	12	36	32	93	7.4
	1992	0.01	13	59	60	113	8.2
	1993	0.02	NA	33	48	94	7.7
Dunce	1990	0.02	15	76	100	129	8.3
	1991	0.15	15	82	78	168	8.5
	1992	0.01	15	74	67	142	8.2

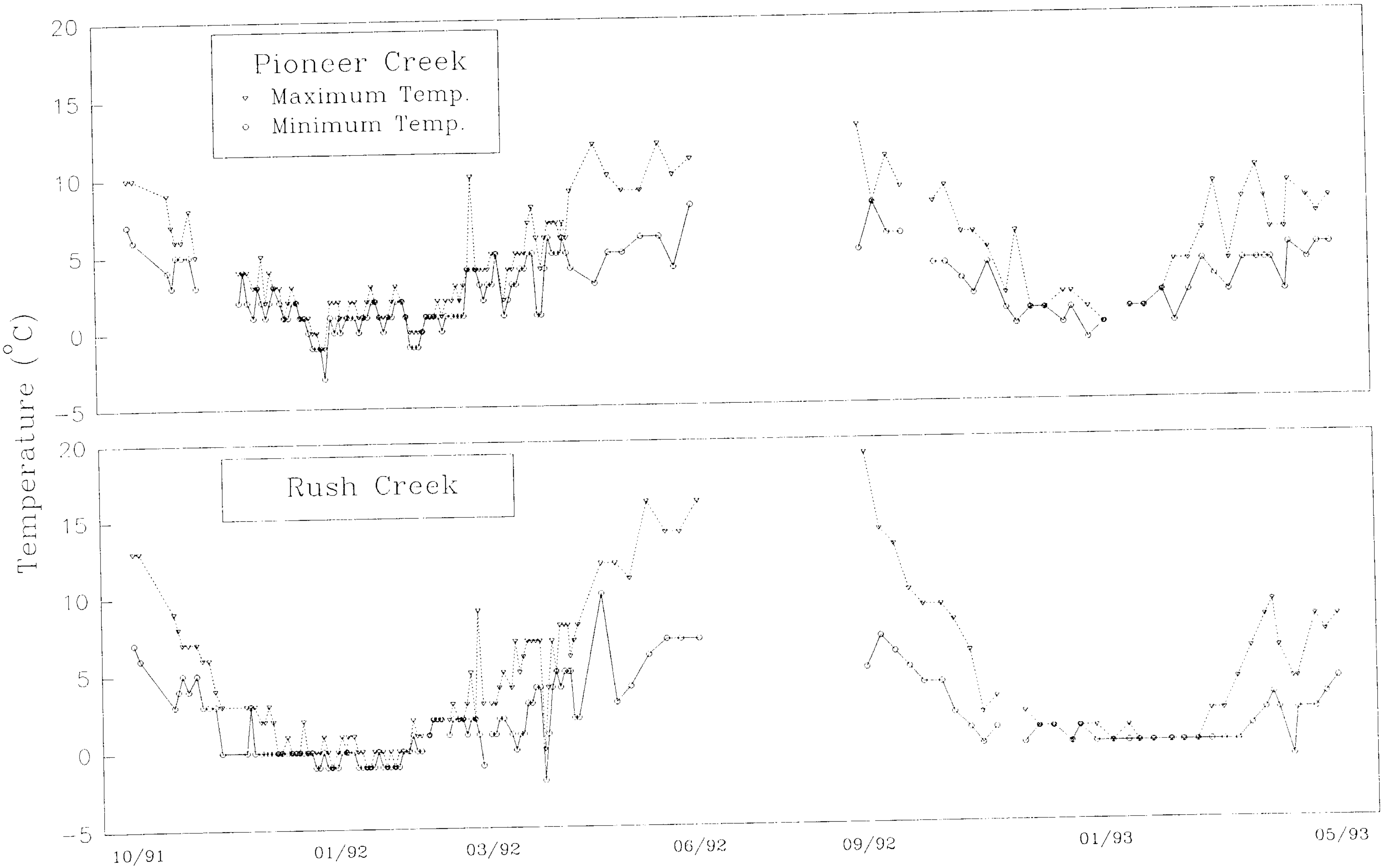

Fig. 1. Maximum and minimum water temperatures for Pioneer and Rush Creeks.

Table 4. Habitat heterogeneity measures for study streams in the Big Creek catchment.

STREAM	Year	Near-bed Velocity (cm/S)		Baseflow Depth (cm)		Bankfull Width (m)		Width:Depth Ratio		Substrate Size (cm)		Substrate Embeddedness (%)	
		mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
Rush	1988	49.0	21.0	35.0	10.0	15.1		43.1		14.6	14.0		
	1992	11.0	6.5	21.0	10.0	12.0		57.1		13.3	9.2	18.8	26.7
	1993	14.7	7.1	26.2	7.3	13.4	1.5	53.8	9.4	21.3	14.8	35.0	28.9
Pioneer	1990	33.0	27.0	16.0	4.5	3.4		21.2		16.7	14.0	12.5	23.9
	1993	17.2	11.9	15.3	7.7	2.9	0.9	25.0	10.9	19.5	18.7	33.8	28.8
Cave	1990			15.0	6.0	6.1		28.0		18.8	12.2		
	1993	14.1	10.9	15.3	8.1	5.4	0.5	31.5	6.9	18.2	17.0	59.8	29.8
Cliff	1990			20.0	4.0	3.5		19.0		25.3	17.7		
	1991			20.0	8.0	3.8		22.5		22.5	20.3		
	1992			20.0	14.0	5.5		34.4		26.8	26.8		
	1993	13.4	11.2	16.4	8.3	3.2	0.7	21.2	10.3	21.5	16.8	41.8	31.6
Goat	1990			10.0	2.0	0.9		16.3		9.7	16.5		
	1991			10.0	3.0	0.9		14.7		10.9	16.4		
	1992			10.0	7.0	0.8		11.6		13.1	17.0		
	1993	14.9	8.5	12.0	4.1	1.1	0.3	11.9	4.2	17.5	16.6	43.8	35.4
Cougar	1990			20.0		2.7		15.4		21.6	13.0		
	1991			20.0	6.0	3.1		16.2		22.6	27.1		
	1992			20.0	20.0	2.6		16.4		13.0	14.3		
	1993	11.9	12.4	16.3	8.1	2.5	0.9	15.4	9.0	21.1	20.9	42.5	30.5
Dunce	1990			10.0	3.0	1.1		20.2		21.3	32.0		
	1991			10.0	2.0	1.1		15.3		13.9	22.2		
	1992			10.0	7.0	1.2		24.4		4.7	14.1		

Table 5. Habitat assessment scores for study streams in the Big Creek catchment.

	SUBSTRATE COVER	SUBSTRATE EMBED.	FLOW TYPES	CHANNEL ALTERATION	DEPOSITION	POOL/RIFFLE RATIO	BANK STABILITY	BANK VEGETATION	RIPARIAN COVER	TOTAL SCORE	PERCENT OF MAXIMUM
Maximum Possible:	20	20	20	15	15	15	10	10	10	135	100
Rush - 1992	15	20	8	15	10	8	9	10	10	105	78
Rush - 1993	20	19	15	15	15	11	10	10	10	125	93
Pioneer - 1993	19	15	13	15	15	14	10	9	10	120	89
Cave - 1993	20	8	17	15	11	13	10	10	10	114	84
Cliff - 1992	18	20	17	15	15	12	10	10	10	127	94
Cliff - 1993	20	16	15	13	11	14	10	9	10	118	87
Goat - 1992	16	18	15	15	14	12	10	10	10	120	89
Goat - 1993	8	10	10	13	12	8	9	10	5	85	63
Cougar - 1992	20	18	15	14	14	11	8	9	10	119	88
Cougar - 1993	18	15	16	13	7	10	9	9	8	105	78
Dunce - 1992	18	14	9	13	14	11	10	10	9	108	80

of the maximum score possible. However, it appears that Goat Creek may have experienced some habitat degradation from 1992 to 1993, particularly in the categories of substrate cover and riparian cover. As with Dunce Creek, Goat Creek also is a small stream (width ca. 1 m) and low habitat scores for some categories may be a result of its size.

Benthic organic matter (BOM) was greater and more variable (higher SD's) in the smaller Goat and Dunce Creeks than any of the other study streams (Fig. 2). However, BOM in Goat Creek has been steadily decreasing from 1991 through 1993 suggesting flushing of deposited material from the 1988 fires. BOM values in the other study streams have remained low (ca. 50 g/m^2 or less) and relatively more constant among years. Generally, percent charcoal was greatest in Goat Creek, particularly in 1992 when 50% of the benthic material was charcoal. Cliff, Cougar, and Dunce Creeks also displayed substantial amounts of charcoal, although all values were reduced from 1992 to 1993. Data from Pioneer and Cave Creeks suggest background charcoal values may be on the order of 10% for wilderness streams.

Generally, periphyton chlorophyll-*a* was greatest in the more open-canopied Rush Creek, although Cave Creek also displayed a high mean value in 1993 (Fig. 3). Cliff Creek displayed a large amount within and among year variability in chloropyll-*a* values suggesting a high degree of habitat patchiness. For example, Cliff Creek displayed one of the highest assessment scores for flow type among the study streams (Table 5). Pioneer, Goat, Cougar, and Dunce Creeks all exhibited relatively low and constant values of chlorophyll-*a* among years reflecting the heavy riparian conditions for these sites. Periphyton ash-free dry mass showed similar trends as chlorophyll-*a* (Fig. 3).

Diatoms were collected from Pioneer, Cliff, and Cougar Creeks in 1990 (Table 6). Taxa richness was lowest in Pioneer Creek (25 taxa), with Cougar (33) and Cliff (35) displaying

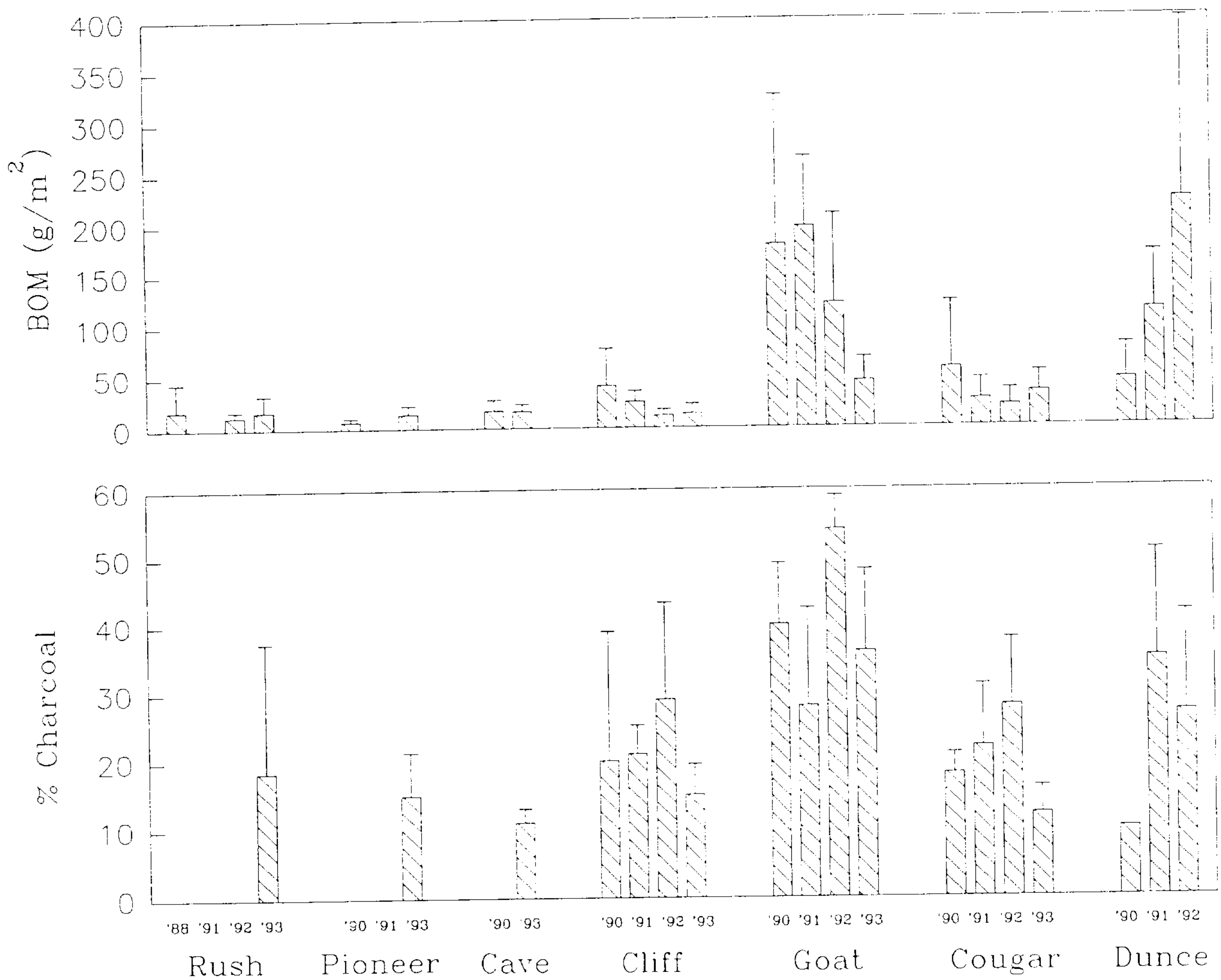

Fig. 2. Benthic organic matter (BOM) and percent charcoal for study streams in the Big Creek catchment. Error bars equal one standard deviation from the mean, n=5 (n=10 in 1988).

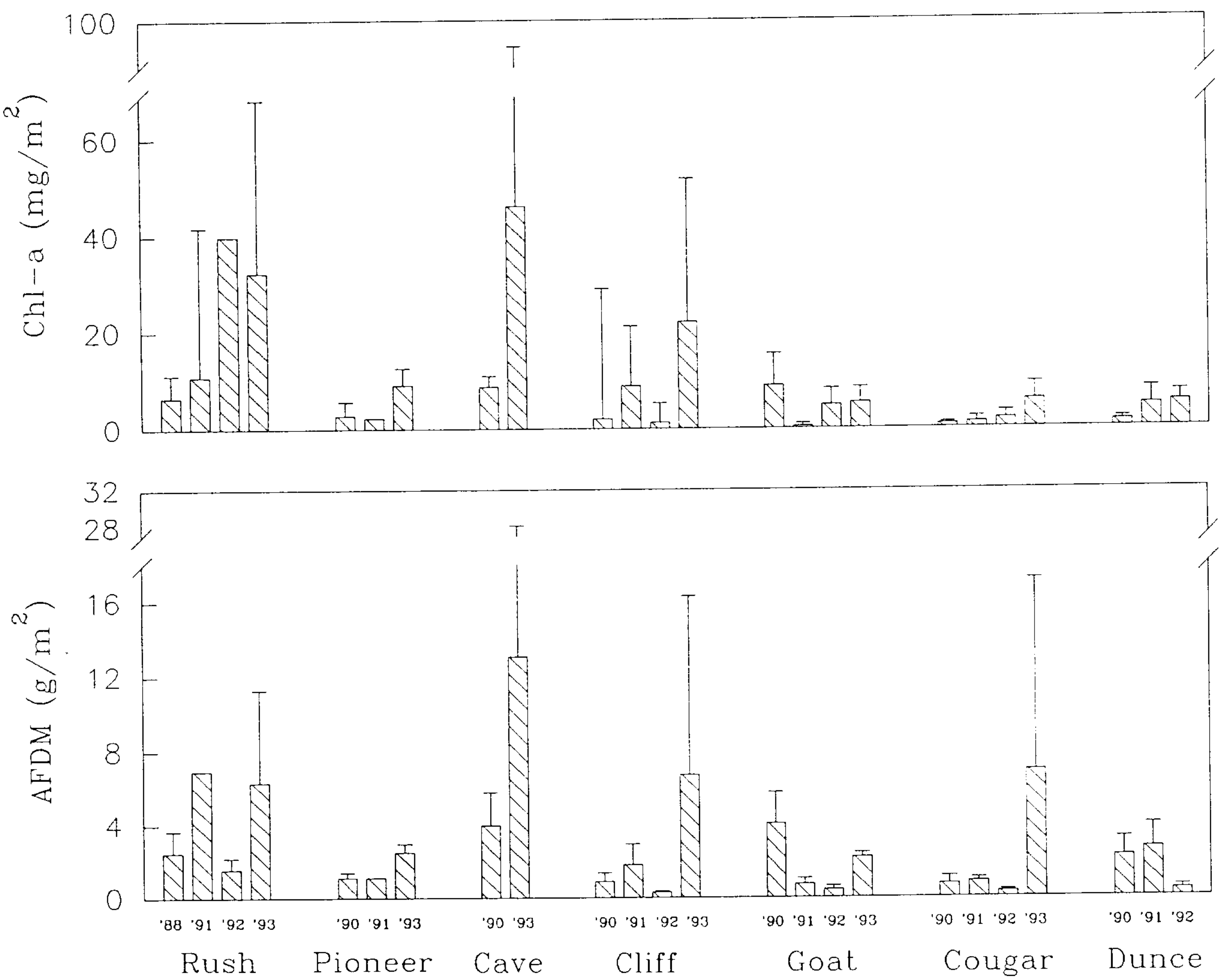

Fig. 3. Periphyton chlorophyll-a and ash-free dry mass (AFDM) for study streams in the Big Creek catchment. Error bars equal one standard deviationfrom the mean, n=5 (n=10 in 1988).

Table 6. Diversity measures and relative abundances of diatom taxa that represented >1% of the community in Pioneer, Cliff, and Cougar Creeks. Samples were collected in 1990.

Taxa	Relative Abund. (%)	Taxa	Relative Abund. (%)
Pioneer Creek		Cougar Creek	
Species Richness	25	Species Richness	33
Simpson's Index	0.17	Simpson's Index	0.19
H' (base 2)	3.15	H' (base 2)	3.20
Achnanthes minutissima	30.9	Achnanthes minutissima	31.1
Achnanthes lanceolata	19.4	Hannaea arcus	26.4
Nitzschia dissipata	15.0	Achnanthes lanceolata	12.3
Navicula radiosa var. tenella	9.1	Fragilaria vaucheriae	4.7
Navicula cryptocephala	4.8	Navicula tripunctata	4.5
Cocconeis placentula var. euglypta	4.2	Diatoma hiemale var. mesodon	2.5
Diatoma hiemale var. mesodon	3.8	Cocconeis placentula var. lineata	1.8
Navicula arvensis	2.1	Cocconeis placentula var. euglypta	1.6
Navicula lanceolata	1.5	Navicula cryptocephala var. veneta	1.6
Navicula tripunctata	1.3	Cymbella minuta	1.3
Achnanthes lanceolata var. dubia	1.1	Nitzschia inconspicua	1.3
		Nitzschia subtilus	1.3
		Nitzschia hantzschiana	1.3
Cliff Creek		Rhoicosphenia curvata	1.1
Species Richness	35		
Simpson's Index	0.12		
H' (base 2)	3.82		
Achnanthes lanceolata	18.6		
Achnanthes minutissima	17.6		
Cocconeis placentula var. euglypta	11.2		
Diatoma hiemale var. mesodon	9.8		
Navicula radiosa var. tenella	7.2		
Cocconeis placentula	6.9		
Nitzschia dissipata	6.9		
Diatoma vulgare	3.2		
Rhoicosphenia curvata	2.4		
Navicula arvensis	1.3		
Navicula cryptocephala var. veneta	1.3		
Nitzschia hantzschiana	1.3		
Hannaea arcus	1.1		
Meridion circulare	1.1		

similar richness. All sites showed low Simpson's values indicative of even assemblage structure, and relatively high diversity values. *Achnanthes minutissima* and *A. lanceolata* were the most common taxa identified for these three streams. *Nitzschia dissipata* also was common (>10% of the assemblage) in Pioneer, *Hannaea arcus* in Cougar Creek, and *Cocconeis placentula* var. *euglypta* in Cliff Creek. The algal flora was comprised mainly of smaller adnate and prostrate diatoms suggesting good habitat quality.

Macroinvertebrate density was greatest in Rush Creek for all sample years prior to 1993 (Fig. 4). Rush Creek displayed a markedly reduced macorinvertebrate density in 1993 (ca. 6000 individuals/m^2) from previous years. However, macroinvertebrate biomass from Rush Creek was only slightly reduced from 1992. This apparent inconsistency may be a result of sampling during different life history stages (later instars) of the various macroinvertebrate taxa. Most sites exhibited average density of ca. 3000 organisms/m^2 and mean biomass of 500-1000 mg/m^2. Most sites displayed reductions in mean macroinvertebrate density in 1993.

Macroinvertebrate richness also was greatest in Rush Creek than the other sites (Fig. 5). Goat and Dunce Creeks showed the lowest richness values among years, again resulting from their relatively small size. Cliff and Cave Creeks had similar, albeit lower, richness values as Rush Creek. In contrast, all sites displayed similar diversity and Simpson's levels suggesting the distribution among taxa within a stream was even.

Chironomidae and oligochaetes were predominant, in terms of relative density, in all sites in 1993 (Table 7). Other taxa that had high relative abundances included *Baetis bicaudatis*, *Zapada columbiana*, and *Heterlimnius*. Specifically, the filterers Simuliidae. and *Brachycentrus* were common in Rush Creek. Plecopterans, in general, were prevalent in Pioneer, and

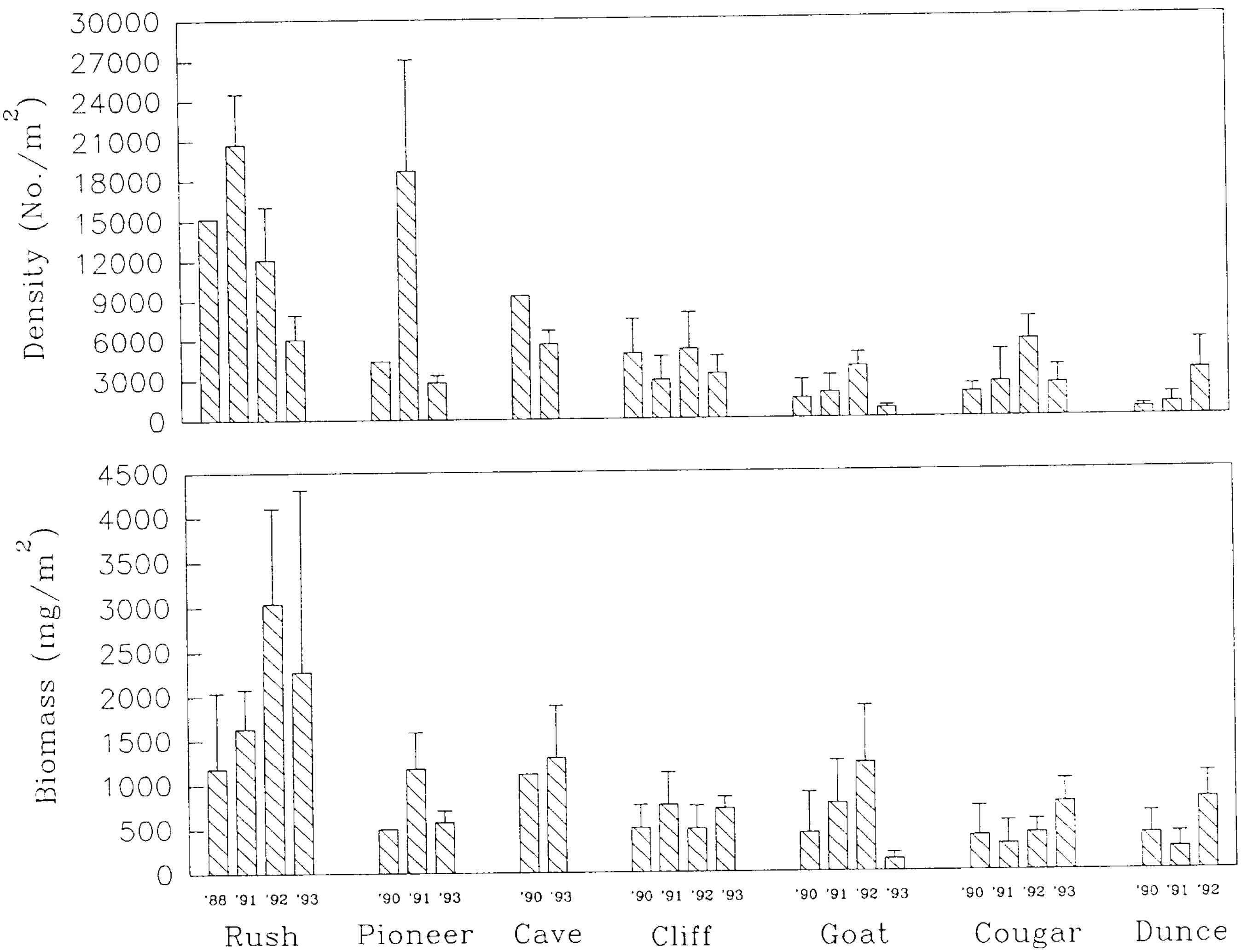

Fig. 4. Macroinvertebrate density and biomass (dry weight) for study streams in the Big Creek catchment. Error bars equal one standard deviation from the mean, n=5 (n=10 in 1988).

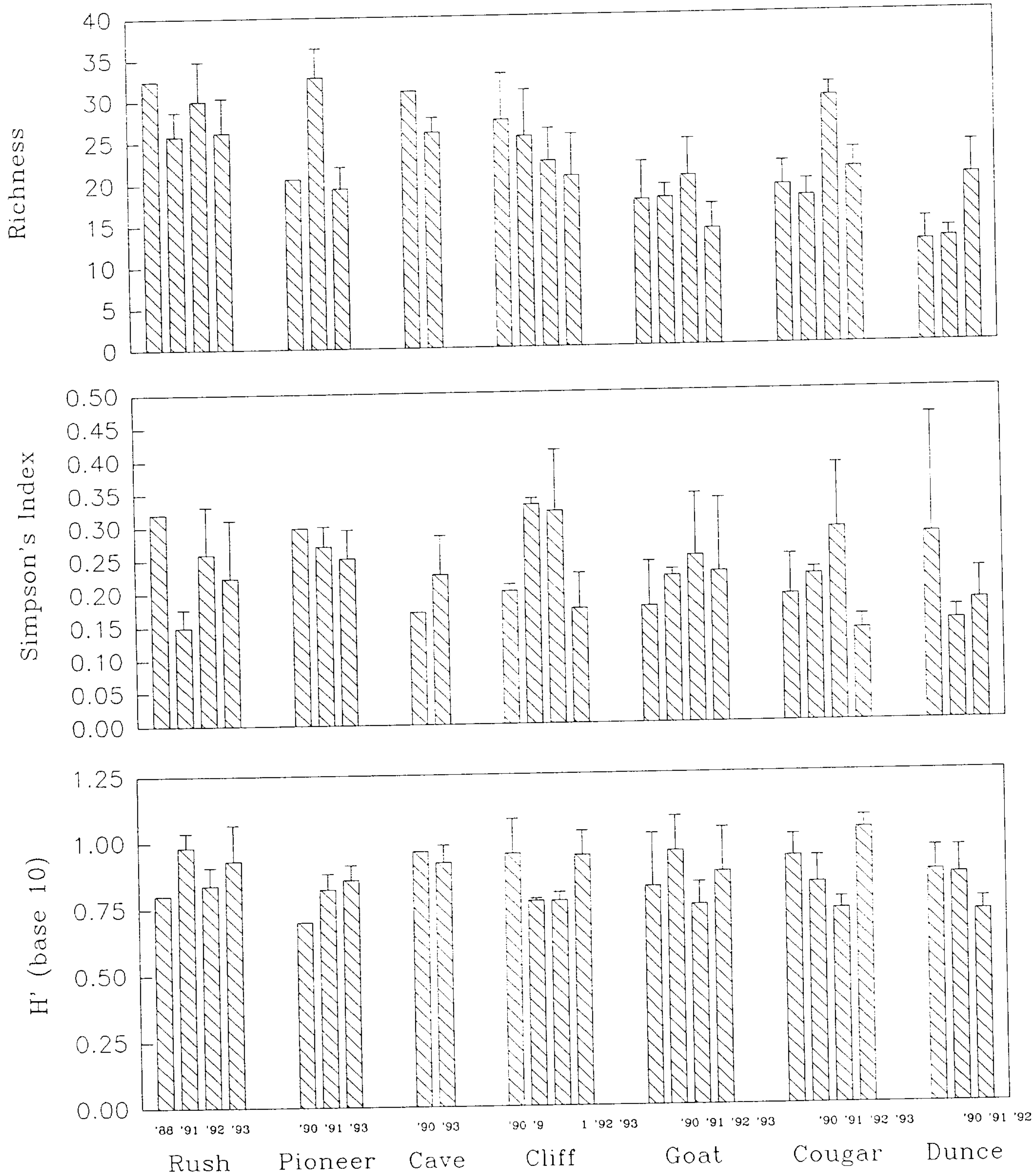

Fig. 5. Macroinvertebrate taxa richness, Simpson's Index, and Shannon–Wiener diversity (H') for study streams in the Big Creek catchment. Error bars equal one standard deviation from the mean, n=5 (n=10 in 1988).

Table 7. Ten most abundant macroivertebrate taxa, based on density in 1993, for study streams in the Big Creek catchment.

	Density (no./m2) Mean	Std.	Rel. Abund. (%)
Rush Cr.			
Chironomidae	2331	321	38.4
Hydracarina	838	500	13.8
Simulium sp.	476	327	7.8
Oligochaeta	349	103	5.8
Zapada columbiana	306	261	5.0
Baetis bicaudatis	266	46	4.4
Brachycentrus sp.	242	397	4.0
Optioservus sp.	236	57	3.9
Hesperoperla pacifica	178	127	2.9
Cinygmula sp.	137	128	2.3
Pioneer Cr.			
Oligochaeta	1304	286	46.3
Baetis tricaudatis	337	101	12.0
Cinygmula sp.	217	68	7.7
Suwallia sp.	202	96	7.2
Heterlimnius sp.	169	97	6.0
Chironomidae	126	25	4.5
Skwala sp.	93	79	3.3
Megarcys sp.	89	18	3.2
Turbellaria	75	38	2.7
Zapada columbiana	67	23	2.4
Cave Cr.			
Chironomidae	2440	730	43.4
Heterlimnius sp.	708	108	12.6
Hydracarina	536	277	9.5
Amiocentrus sp.	346	196	6.2
Baetis tricaudatis	254	127	4.5
Skwala sp.	251	82	4.5
Oligochaeta	176	103	3.1
Baetis bicaudatis	167	110	3.0
Visoka cataractae	150	0	2.7
Oreogeton sp.	129	0	2.3

	Density (no./m2) Mean	Std.	Rel. Abun (%)
Cliff Cr.			
Oligochaeta	930	461	28.0
Chironomidae	600	385	18.1
Baetis bicaudatis	412	219	12.4
Zapada columbiana	307	290	9.2
Capnia sp.	249	134	7.5
Heterlimnius sp.	197	142	5.9
Drunella doddsi	168	60	5.1
Cinygmula sp.	122	92	3.7
Epeorus deceptivus	96	43	2.9
Rhyacophila vagrita	92	93	2.8
Goat Cr.			
Chironomidae	247	201	36.0
Heterlimnius sp.	146	74	21.3
Zapada columbiana	59	16	8.6
Baetis bicaudatis	45	25	6.6
Chelifera sp.	43	0	6.3
Suwallia sp.	39	33	5.7
Nematoda	32	0	4.7
Simulium sp.	32	12	4.7
Capnia sp.	27	12	3.9
Hydracarina	27	16	3.9
Cougar Cr.			
Zapada columbiana	525	459	21.4
Oligochaeta	414	227	16.8
Chironomidae	377	226	15.3
Hydracarina	211	239	8.6
Dolophilodes sp.	193	126	7.8
Heterlimnius sp.	176	95	7.1
Ostracoda	134	113	5.4
Baetis tricaudatis	124	48	5.1
Simulium sp.	99	58	4.0
Serratella sp.	78	38	3.2

Amiocentrus was abundant in Cave Creek. The scrapers *Cinygmula, Epeorus deceptivus,* and *Drunella doddsi* were predominant in Cliff Creek, while *Dolophilodes* was found in Cougar Creek.

Rapid River Catchment

We presently have data from six streams from the Rapid River catchment, with two of these sampled in 1992. Discharge ranged from 0.03 (Castle and Lake Fork Creeks) to 1.80 (W.F Rapid River) m^3/s (Table 8). Streams typically were of high gradient (>2% slope), and displayed low values for alkalinity and total hardness. Specific conductance ranged from 51 μmhos in Granite Creek to 183 μmhos in Castle Creek. Phosphorus levels were low for all study streams, however Paradise and Copper Creeks displayed elevated nitrate levels (0.34 and 0.27 mg/L NO_3, respectively). The relatively high nitrate values may have resulted from fires in the headwaters of these two systems.

Near-bed velocities ranged from a low 10 cm/s in Castle Creek to a high a 24 cm/s in Paradise Creek (Table 9). Castle Creek also had the shallowest mean water depth (9.3 cm), while W.F. Rapid River was deepest (24.7 cm mean depth). Bankfull water width ranged from <2 m for Castle Creek to about 10 m for W.F. Rapid River. Width:Depth ratios were similar among sites, with Granite Creek (52) displaying the highest value. Substrate size was greater in the upper basin (i.e. Paradise and Lake Fork Creeks), than downriver in Castle Creek and W.F. Rapid River. Mean embeddedness values were relatively low for all sites, with Granite Creek showing the highest value (57% embedded).

Chlorophyll-*a* values averaged around 10 mg/m^2 for all sites except Granite Creek which was 4X higher (Fig. 6). In contrast, W.F. Rapid River displayed the highest AFDM levels, and Paradise, Copper, and Lake Fork the lowest. Benthic organic matter ranged from ca. 10 g/m^2 in Paradise to over 60 g/m^2 in Copper Creek. No

Table 8. Physical and chemical measures for study streams in the Rapid River catchment.

STREAM	Discharge (m3/s)	Slope (%)	Alkalinity (mg CaCO3/L)	Hardness	Specific Conductance (umhos @ 20C))	Nitrate NO3 (mg/l)	Phosphorus o-PO4 (mg/l)
Paradise Creek	0.20	10	25	44	86	0.34	0.01
Copper Creek	0.10	NA	36	60	95	0.27	0.01
Lake Fork Creek	0.03	NA	NA	NA	NA	0.03	0.01
Granite Creek	0.10	NA	16	36	51	0.04	0.01
W.F. Rapid River - 1992	1.80	3	39	20	90	NA	NA
Castle Creek - 1992	0.03	12	72	30	183	NA	NA

Table 9. Habitat heterogeneity measures for study streams in the Rapid River catchment.

STREAM	Near-bed Velocity (cm/s)		Baseflow Depth (cm)		Bankfull Width (m)		Width:Depth Ratio		Substrate Size (cm)	
	mean	std	mean	std	mean	std	mean	std	mean	std
Paradise Creek	24.5	17.9	20.2	15.1	5.44	2.37	22	11	41.7	39.2
Copper Creek	20.9	16.1	16.6	9.9	4.73	1.13	28	15	28.2	25.5
Lake Fork Creek	14.2	13.1	16.8	13.2	4.76	0.95	32	17	27.4	31.6
Granite Creek	18.8	11.6	18.4	12.5	8.72	3.58	52	22	17.9	23.3
W.F. Rapid River - 1992	20.0	10.0	24.7	11.7	9.52	1.67	41	9	13.4	10.3
Castle Creek - 1992	10.0	10.0	9.3	5.1	1.89	0.34	26	6	10.0	11.7

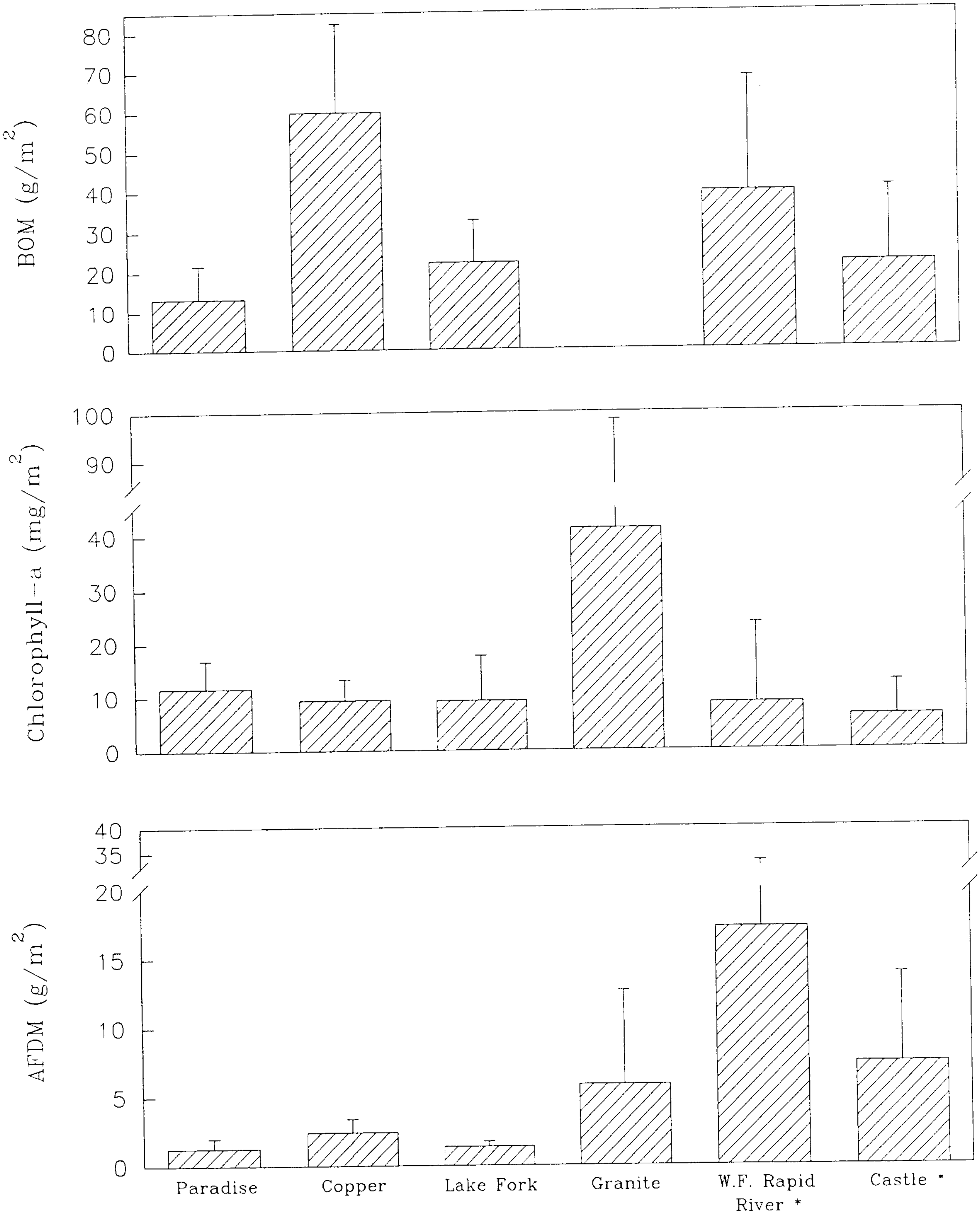

Fig. 6. Benthic organic matter (BOM), periphyton chlorophyll-a, and periphyton ash-free dry mass (AFDM) for study streams in the Rapid River catchment. Error bars equal one standard deviation from the mean, n=5; * indicates streams sampled in 1992, n=10.

benthic data were available for Granite Creek because of lost samples.

W.F. Rapid River and Castle Creek displayed the greatest density of macroinvertebrates (ca. 7500 organisms/m^2)(Fig. 7). Other sites showed densities around 3000-4000 organisms/m^2. W.F. Rapid River and Castle Creek also had the highest mean biomass values 1000-1500 mg/m^2, although Lake Fork showed a similar value as Castle Creek. Copper and Paradise Creeks exhibited a mean biomass of 500 mg/m^2.

W.F. Rapid River and Castle Creek had 10-15 additional taxa from that found in Paradise, Lake Fork, and Copper Creeks (Fig. 8). Indeed, around 40 taxa were identified from Castle Creek, whereas only 18 taxa were found in Copper Creek. Simpson's index was <0.20 for all sites suggesting an even distribution among taxa. Diversity was relatively high among sites, being greater than 3.1. Although, Castle Creek displayed the highest diversity.

Chironomidae, oligochaetes, and *Baetis bicaudatis* were predominant in all sites, except oligochaetes displayed low abundances in Lake Fork (Table 10). *Visoka cataractae* was abundant (>10% of the assemblage) in Copper Creek. *Heterlimnius, Drunella doddsi,* and *Micrasema* were common in Castle Creek. *Drunella coloradensis, Rhithrogena robusta, Suwallia,* and *Cinygmula* also were predominant in Lake Fork Creek.

DISCUSSION

Big Creek Catchment

Habitat measures for study streams in the Big Creek catchment have shown little change among the years of study. Flow data and width:depth ratios suggest high flows from snowmelt

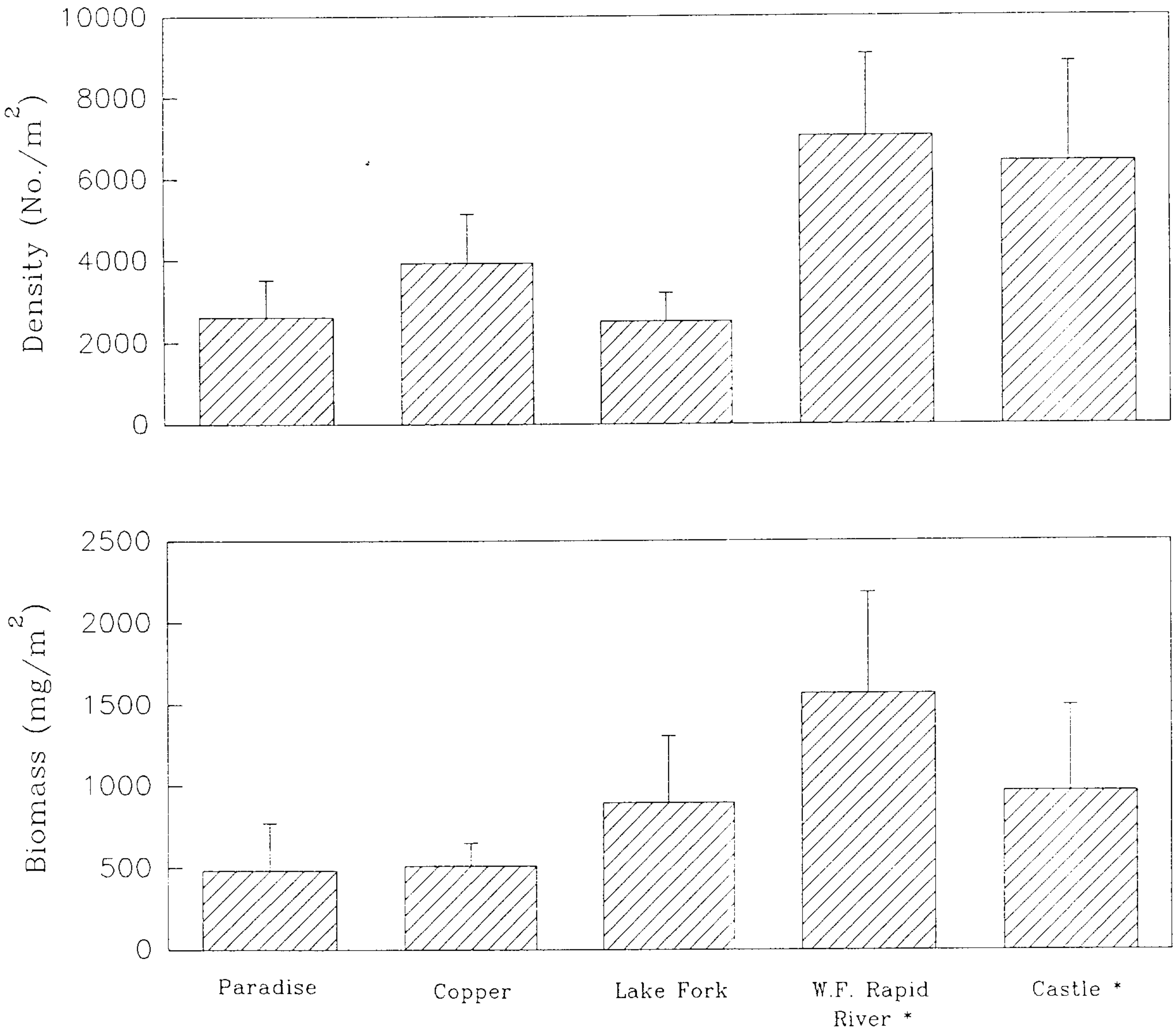

Fig. 7. Macroinvertebrate density and biomass for study streams in the Rapid River catchment. Error bars equal one standard deviation from the mean, n=5; * indicates streams sampled in 1992, n=10.

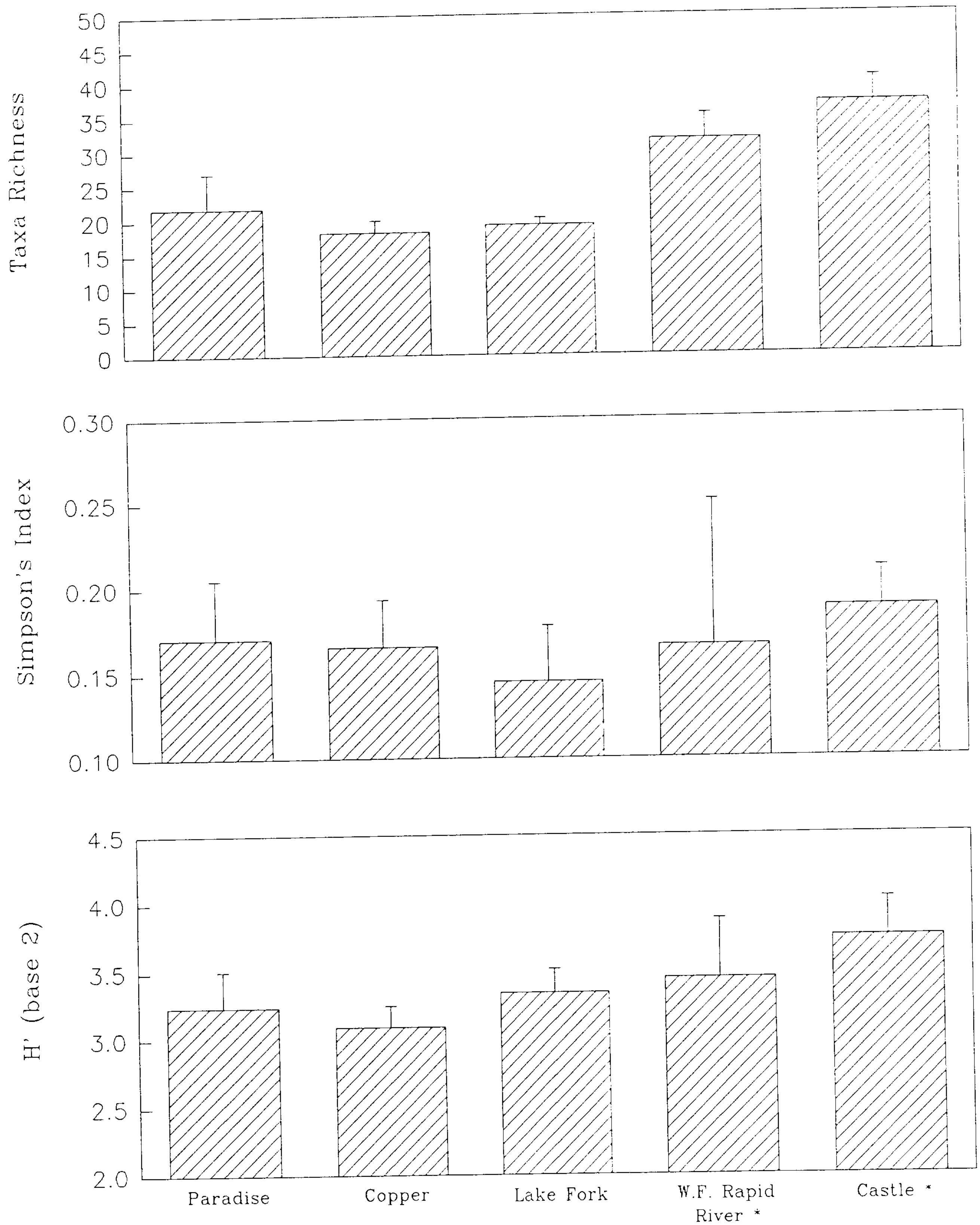

Fig. 8. Macroinvertebrate taxa richness, Simpson's Index, and Shannon–Weiner diversity for study streams in the Rapid River catchment. Error bars equal one standard deviation from the mean, n=5; * indicates streams sampled in 1992, n=10.

Table 10. Ten most abundant macroinvertebrate taxa, based on density, for study streams in the Rapid River catchment.

	Density (No./m2) Mean	Std.	Rel. Abund. (%)
Paradise Creek			
Oligochaeta	825	338	31.5
Chironomidae	440	136	16.8
Baetis bicaudatis	251	263	9.6
Rithrogena robusta	158	126	6.0
Cinygmula sp.	134	94	5.1
Capnia sp.	131	39	5.0
Suwallia sp.	121	29	4.6
Turbellaria	118	47	4.5
Ostracoda	96	0	3.7
Nematoda	80	48	3.1
Copper Creek			
Chironomidae	911	320	23.2
Baetis bicaudatis	900	433	22.9
Oligochaeta	531	405	13.5
Visoka cataractae	394	212	10.0
Ostracoda	370	284	9.4
Rhyacophila vagrita	354	128	9.0
Suwallia sp.	197	130	5.0
Cinygmula sp.	133	26	3.4
Zapada columbiana	118	65	3.0
Rhabdomastix sp.	113	16	2.9
Lake Fork Creek			
Baetis bicaudatis	489	251	19.3
Chironomidae	429	164	17.0
Drunella coloradensis	418	93	16.5
Rithrogena robusta	284	80	11.2
Suwallia sp.	259	232	10.3
Cinygmula sp.	255	198	10.1
Drunella doddsi	182	150	7.2
Yoroperla brevis	169	65	6.7
Rhyacophila vaccua	123	5	4.9
Zapada columbiana	107	81	4.2
WF Rapid River - 1992			
Oligochaeta	2151	1634	30.5
Chironomidae	1013	502	14.4
Baetis bicaudatus	813	501	11.5
Heterlimnius sp.	383	256	5.4
Cinygmula sp.	359	114	5.1
Paraleptophlebia sp.	308	122	4.4
Nematoda	248	330	3.5
Ostracoda	243	342	3.5
Serratella tibialis	181	81	2.6
Suwallia sp.	166	99	2.4
Castle Creek - 1992			
Baetis bicaudatus	1230	1100	19.2
Heterlimnius sp.	1105	432	17.2
Drunella doddsi	793	585	12.4
Micrasema sp.	701	350	10.9
Chironomidae	427	260	6.7
Oligochaeta	272	181	4.2
Zapada columbiana	227	158	3.5
Rhyacophila vagrita	163	99	2.5
Cinygmula sp.	126	80	2.0
Megarcys sp.	124	79	1.9

runoff in 1993 were comparable with previous spring runoffs. Indeed, discharge values were actually lower for some sites in 1993 than in previous study years. Percent embeddedness, initially measured in 1993, was about 1.5-2X greater in south-facing streams than in north-facing streams (Pioneer and Rush). This finding also was evident in the more subjective habitat assessment scores for substrate embeddedness and degree of sediment deposition. Further, average substrate sizes were smaller in these north-facing streams compared to similarly sized south-facing streams. Both measures suggest subtle habitat differences among north- and south-facing streams which ultimately may be reflected in the structural and functional properties of the biota. Sampling of additional north-facing streams would greatly contribute to future analyses.

Benthic organic matter (BOM) and %charcoal of the BOM was greater in the burn streams than in respective reference streams suggesting an influence of the Golden Fire in 1988 on organic matter properties. Percent charcoal values for Cave and Pioneer Creeks suggest charcoal background levels to be around 10%. Percent charcoal in the burn streams typically was 20-40% of the BOM and potentially can impact some benthic organisms (Mihuc 1994).

Chlorophyll biomass generally was inversely correlated with the degree of canopy cover. For example, Rush Creek displayed the greatest periphyton biomass values and had an open canopy at the study reach. In contrast, Pioneer, Dunce, Cougar and Goat Creeks had lower periphyton levels and also dense riparian zones (>75% canopy cover). Diatoms, common freshwater algae, typically were comprised of small adnate or prostrate varieties such as *Achnanthes* and *Cocconeis* groups. Indeed, *Achnanthes minutissima*, an extremely small adnate diatom, was predominant for the three streams analyzed.

Rush Creek had dramatically greater density and biomass of macroinvertebrates than any other stream and may be simply a function of its larger size. Filterers, especially Simuliidae and *Brachycentrus*, were quite common in Rush Creek, suggesting a high amount of organic matter in transport. Fine particulates commonly were observed on substrate surfaces (C.T. Robinson, personal observation).

Macroinvertebrate density, biomass, and richness were lower in burn streams than in the reference Cave Creek suggesting a possible influence from the Golden Fire in 1988. However, Cliff Creek still maintained high macroinvertebrate density and biomass suggesting minimal influence from this fire. An attempt will be made in 1994 to sample Cliff Creek within the fire perimeter to see if this trend holds there also.

The data from Pioneer and Cave, both similar-sized streams, suggest a possible north- versus south-facing influence on benthic structure and function. Here, Pioneer showed lower density, biomass and richness during two years of study than that found in Cave Creek. The fauna also was quite different. Pioneer had a predominance of *Cinygmula* and *Baetis bicaudatis*, whereas *Heterlimnius* and *Amiocentrus* were prevalent in Cave. The data suggest possible food resource differences or habitat conditions between north- and south-facing streams. However, the data are confounded by the differences in burn histories of the various catchments and additional research is required to substantiate these premises and the potential influence on the fisheries.

Rapid River Catchment

Because of logistic constraints we were unable to sample Paradise or Copper Creeks within the area of the 1992 fires. Consequently, we expected little influence to be evident in these streams downstream of the fire perimeters, as was found for Cliff

Creek in the Big Creek catchment. However, analytical data revealed that nitrate concentrations were an order of magnitude higher in these two streams than in respective reference sites. Our studies on streams influenced by the Yellowstone fires also showed elevated nitrate levels in the more disturbed streams. This suggests that Paradise and Copper Creeks may be physically altered within the fire perimeter, with downstream areas displaying minimal physical impact, as was found in the present study. These three sites, Cliff, Paradise, and Copper, provide the unique opportunity to assess downstream impacts in small streams where fires are restricted to a portion of their headwaters.

The macroinvertebrate data also suggest a potential aspect-effect on stream structure and function. For example, Paradise and Copper Creeks showed a predominance of chironomids and oligochaetes, whereas Castle Creek displayed a prevalence of *Heterlimnius*, *Drunella doddsi,* and *Micrasema*. As with Big Creek streams that differ in aspect, these results imply a potential and subtle difference in benthic habitat and/or food resources and provide a valuable avenue for future research.

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